Determinants of Recent Trade Flows in OECD Countries: Evidence from Gravity Panel Data Models

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Abstract

This paper aims to identify the main causes of recent trade flows in OECD countries. The specific features of the study include the explicit introduction of R&D and FDI as the two important explanatory variables, unit root tests in the panel data framework and careful treatment of endogeneity. The main findings are that the levels and similarities of market size, domestic R&D stock and inward FDI stock are positively related to the volume of bilateral trade, while the distance between trading countries has a negative impact. These findings lend support to new trade, FDI and economic growth theories.

Keywords: Trade, R&D, Foreign Direct Investment, Income Convergence, Gravity Equation.

JEL classification: F12

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I. Introduction

International trade plays an important role in economic growth. It promotes competition, specialisation and scale economies, and helps resource allocation based on comparative advantage. It is an important channel for knowledge spillovers across boarders (Grossman and Helpman, 1991). International trade has grown faster than income in the post-war period (Hill, 2001). The identification of main sources of international trade flows has been a subject of considerable interest to academics for many years.

In empirical studies of foreign trade flows the gravity model has been widely used. In its original form, the gravity equation specifies that bilateral trade flows are determined by the economic sizes of, and the bilateral distance between, the two countries (see Tinbergen 1962 and Poyhonen 1963). Trade theories based upon imperfect competition and the Hechsher-Ohlin model justify the inclusion of the core variables – income and distance (Ghosh and Yamarik 2004). Since then, this model has been extended by adding variables such as border effects (e.g. Aitken, 1973; Frankel and Wei, 1995; Frankel and Rose 2002; de Groot et al. 2003; Rose, 2004), infrastructure availability and/or landlocked/island effects (e.g. Rose, 2000; Frankel and Rose, 2002; Wilson et al. 2003; Longo and Sekkart, 2004; Rose, 2004), historical or colonial ties (e.g. Frankel and Wei, 1995; Feenstra et al. 2001; Frankel and Rose, 2002; de Groot et al. 2003), exchange rate or currency risk (e.g. Frankel and Wei, 1993; Klein, 2002), trade or economic policy (e.g. Coe and Hoffmaister, 1999; Wilson et al. 2003; Longo and Sekkart, 2004), economic development (e.g. Frankel, 1997; Frankel and Rose, 2002), and relative factor endowments (e.g. Frankel et al. 1995; Egger and Pfaffermayr, 2004).

In the literature there is no consensus on which other variables should be included in the extended model. To deal with this problem, Ghosh and Yamarik (2004) apply an extreme bounds analysis to test the robustness or fragility of various coefficient estimates. The current paper attempts to provide an alternative extension of the gravity model for analysing trade flows in OECD countries in the 1980s and the 1990s. It differs from many other studies in the following three aspects. First, guided by new trade, foreign direct investment (FDI)[1] and new growth theories, R&D and FDI stocks are included as the additional explanatory variables. Second, the time series properties and the relationship of trade flows and its explanatory variables justified by economic theory are examined to check the possible long run or stable relationship between them. Third, it takes into consideration possible endogeneity of income, R&D and FDI stocks and applies the generalised method of moments (GMM) to deal with endogeneity biases.

[1] The terms of MNE and FDI are often used interchangeably because, by definition, an MNE is a firm engaging in FDI.

The rest of the paper is organised as follows. Section II considers the guidance from new trade, FDI and new growth theories regarding the sources of international trade flows. Section III extends the standard gravity model to incorporate R&D and FDI stocks. Section IV presents the empirical results, and finally conclusions are offered in Section V.

II. Theoretical Considerations

As indicated in the preceding section, the existing extension of the gravity model tends to focus on boarder effects, landlocked or island locations, historical or colonial ties and economic policy. While these explanatory variables are found to be significant in some studies, one criticism is that "for the most part researcher have extended the gravity model beyond the core in an ad hoc fashion" (Ghosh and Yamarik, 2004). The current study applies an extended gravity model and our selection of explanatory variables is guided by economic theory. As mentioned earlier and discussed in detail below, the level of GDP (income) and geographic distance are the core gravity equation variables and can be justified by the Hechsher-Ohlin model and new trade theories based on imperfect competition. In addition, the inclusion of the relative factor endowment, similarity of GDP, R&D accumulation and similarity, FDI accumulation and similarity can be justified by new trade, FDI and new growth theories. This section discusses the roles of these driving forces behind international trade flows and develops the corresponding hypotheses.

<u>II.1 Relative factor endowment</u>

Based on the assumptions of constant returns to scale and perfect competition, neo-classical trade theory represented by the Heckscher-Ohlin model concludes that international trade is explained by comparative advantages resulting from differences in factor endowments[2] (including labour, capital, natural resources and technology) among nations. Capital rich countries should export capital-intensive goods and import labour-intensive good, while labour rich countries should do the opposite. The popularity of this theory is mainly due to its success in explaining inter-industry trade which is the main part of North-South trade.

Today more than half of international trade takes place among industrialised countries (WTO, 2002). Furthermore, as indicated in Table 1, the dominant part of trade in modern economies involves the exchange of differentiated products in the same industry, i.e. intra-industry trade. To explain this, Helpman (1981), Krugman (1980), and Lancaster (1980), among others, have developed various theoretical models based on product differentiation, economies of scale and external economies. Inter-industry trade is likely to be larger when the difference in factor endowments among nations is greater. However, intra-industry trade is likely to be larger among economies of similar size and factor proportion. As a substantial proportion of trade in OECD countries is intra-industry trade, the volume of total trade tends to be positively associated with that of intra-industry trade. As a result, the difference in factor endowments is likely to be negatively related to the volume of total trade in OECD

[2] In this analysis, factor endowments are measured by factor proportions, i.e. the capital - labour ratio. Throughout the study, the factor endowment, factor intensity and capital/labour ratio are therefore used interchangeably.

countries. Put another way, the larger the difference in factor endowments, the smaller the volume of intra-industry and therefore total trade.

<Table 1 Here>

II.2 Level and Similarity of GDP

Basic macroeconomic theory suggests that a country's imports are positively determined by its national income. In the case of bilateral trade, the levels of GDP in both countries should positively affect their total trade. New trade theory regards economies of scale as a very important determinant of modern trade (Helpman, 1981; Krugman, 1980). The level of GDP can also be used as a rough proxy for a country's scale economies. At a larger scale of operation a greater division of labour and specialisation becomes possible. This may permit the introduction of more specialised and productive machinery than would be feasible at a smaller scale of operation. From demand side, Linder's (1961) "preference similarity" or "overlapping demands" hypothesis argues that trade in manufactures is likely to be largest among countries with similar tastes and income levels. Helpman and Krugman (1985), Helpman (1988) and Hunter and Markusen (1988) also suggest that convergence in levels of income leads to increased international trade. Bergstrand (1990) indicates that the scope for exchange of product diversity is broadened the smaller the inequality between two countries' economic sizes.

The positive relationship between international trade flows and the level and similarity of GDP has been confirmed in a number of empirical studies (for recent examples, see Egger, 2000 and Ghosh and Yamarik, 2004). From both the theoretical and empirical literature, the general view is that the higher the levels of GDP, the higher the total trade between the trading partner; and the more similar in terms of GDP, the higher the intra-industry trade and hence the total trade between the trading partner.

II.3 R&D accumulation and similarity

The explicit treatment of technology (R&D) as a determinant of trade flows was first made by Posner (1961) who argues that the country hosting a particular invention or innovation activity will have a technological lead over other countries. This country will be able to export the good concerned even though it may not have an apparent comparative advantage in terms of relative factor endowments.

In the case of bilateral trade, if both partner countries are similar in technological capabilities, a high volume of intra-industry trade will be expected. This similarity hypothesis is consistent with predictions by both neo-classical and new trade theories. Within an H-O-V framework, Davis (1995) concludes that intra-industry trade arises quite naturally in a constant-return setting due to excellent substitution possibilities across goods in production. More recently, new trade theorists such as Grossman and Helpman (1991) suggest that if R&D efforts are directed towards horizontal product differentiation, innovation will consist in products serving new functions and, consequently, expanding the possibility of variants, or in specialising production, which are the two determinants of utility value of consumption. The higher the utility, the larger the trade volume could be. By contrast, if R&D efforts are directed towards vertical product differential, innovation will consist in scientific breakthroughs, leading to more efficient production processes or products of higher quality. Trade in vertically differentiated products leads to intra-industry trade. Brander (1981) develops an idea of 'reciprocal trade': trade is two-way in identical products. The phenomenon is sometimes called 'cross-hauling' or 'reciprocal dumping'. It will occur under a wide variety of cases, including Berstrand and Cournot imperfect competitions. Furthermore, the increasing return to scale can account for trade in goods that are technological alike but differentiated in the eyes of consumers (Krugman, 1979).

As the main source of technological enhancement is R&D, increased R&D investment has a positive effect on trade performance due to increased product variety and quality. If partner countries are similar in R&D efforts, their technological capabilities will be similar. In summary, R&D accumulation and similarity induce high volume of international trade because they not only are responsible for improvement on the quality of goods or increased number of variety, but also account for the reciprocal intra-industry trade. Surprisingly, few empirical studies use technological capabilities and similarity to explain international trade[3].

II.4 FDI accumulation and similarity

Early trade theories did not provide an explicit discussion of the role of FDI, although the importance of MNEs in the conduct of international trade had been recognised for decades. Helpman (1984, 1985) incorporates MNEs to his new trade theory and concludes that the existence of these firms has a significant effect on the volume of trade and the share of intra-firm trade when compared with the results obtained for the single product firm. Markusen (1983) demonstrates that along the dynamic path of adjustment, FDI and exports grow simultaneously as complements over time if trade is not based on different factor endowments.

Based on the assumption that countries are symmetric in terms of size, factor endowments and technologies, Brainard (1993) and Horstman and Markusen (1992) show that if proximity advantages overweigh concentration advantages, FDI and trade can be substitutes. However, if concentration advantages overweigh proximity advantages, FDI and trade can be complements. Brainard (1993) further points out that multinational activities are more likely the more similar are the home and foreign markets.

Baier and Berstrand (2001) suggest that greater vertical specialisation and outsourcing may have contributed to greater international trade. As the production process 'disintegrates' internationally and MNEs become more vertically specialised, trade in intermediate goods across borders increases substantially relative to output. FDI not only directly contributes to intra-firm trade, but also introduces more varieties of products. According to Helpman (1984), when the relative country size is given, the

[3] Filippini and Molini (2003) include the technological distance variable in their extended gravity model to examine the relevance of the technology gap between countries in the determination of trade flows.

volume of trade increases with the number of varieties in the exporting country which is proxied by the number of MNEs. Thus, international trade is positively related to inward FDI stock.

Furthermore, if trade partners have similar volumes or patterns of FDI stock, relatively balanced trade can be expected. The trade created in this way may be higher than the trade when inward FDI stocks are unevenly distributed among the trading partners. Markusen (1998) summarises that MNEs are associated with high ratios of R&D relative to sales, and therefore with relatively new and/or technically complex products. If the sizes of inward FDI stock are similar between the trading partners, similar varieties and volumes of bilateral export can be expected from each partner. Thus, the import capabilities of both countries are similar, and this allows for relatively large bilateral trade. If FDI is accumulated unevenly, the partner with a small FDI stock and therefore small export capabilities will have small import capabilities. This negatively affects its trading partner's exports and therefore total bilateral trade.

While it is possible that FDI and trade substitute for each other, a number of theoretical and empirical studies tend to suggest a positive relationship between the two variables (examples of such empirical studies include Pfaffermayr, 1996; Pain and Wakelin, 1998; Gopinath et al, 1999; Liu et al, 2001). Thus, it can be argued that the larger and the more similar the FDI stocks accumulated in the trading partners, the higher the bilateral trade will be between them.

II.5 Geographical distance

In the literature of economic geography, proximity to market or geographic distance is considered to be an important determinant of the choice of trade activities. Distance directly increases transactions costs because of the transportation costs of shipping products, the costs of acquiring information about other economies, and the costs of finding a partner and contracting at a distance. Therefore, the greater the geographic distance between the trading partners, the higher will be the cost of trading activities. Many studies using gravity models confirm that geographical distance matters greatly for international trade (e.g. Egger, 2000). Gopinath and Echeverria (2004) find that physical distance causes countries to switch from exports to FDI-based production.

III. Empirical Model, Data and Methodology

The hypotheses developed in the preceding section can be tested in a gravity equation framework. The gravity model has been widely used in explaining bilateral trade flows. It is sometimes seen as the most successful empirical trade device (Anderson 1979) and is one of the great success stories in empirical economics (Feenstra et al, 2001). Formal theoretical foundations have already been provided by Anderson (1979), Bergstrand (1985, 1989, 1990), Helpman and Kurgman (1985, ch 8), Deardorff (1998), and Feenstra et al (2001), among others. The resulting empirical specification from these theoretical discussions is a double-log relation between trade flows and its explanatory variables (Longo and Sekkart, 2004). Based on economic theory, the current study augments the original gravity model by incorporating R&D and FDI stock to explain recent trade flows in OECD countries. It also applies recently developed panel data techniques to examine the properties and long-run relationships of trade flows and its explanatory variables.

III.1 Extension of Gravity Model and Measurement of Variables

In its original form, a gravity function contains GDP and the transaction and transportation cost variables only and is conventionally specified as

$$EX_{ij} = \frac{A(GDP_i GDP_j)^{r_1}}{D_{ij}^{r_2}} \quad (1)$$

where γs are elasticities. EX_{ij} is the value of exports from country i to j. GDP_i and GDP_j are GDP of countries i and j respectively. D_{ij} is a measure of the distance between the two countries, which captures transaction and transportation costs. A is often treated as a constant in previous literature. However, this kind of treatment of A may be inappropriate because of the existence of heterogeneity across countries. In this study, individual country effects are allowed to vary across countries and specified as a function of its exporting capabilities to its trading partner j. Thus, A_{ij} can be seen as a function of the interaction between its own R&D activities and its partner country's R&D activities (Coe and Helpman, 1995; Coe et al, 1997). Furthermore, a country's R&D activities depend on its domestic R&D efforts and inward FDI (Balasubramanyam et al, 1996). As explained in the preceding section, R&D efforts and inward FDI are closely related to a country's export capabilities. Thus,

$$A_{ij} = e^{r_i}(DRDS_i DRDS_j)^{r_3}(FDS_i FDS_j)^{r_4} \quad (2)$$

where $DRDS_{i(j)}$ and $FDS_{i(j)}$ are country i(j)'s domestic R&D stock and total inward FDI stock, respectively.

Substitute equation (2) into equation (1) and take logs, we have

$$\begin{aligned} \ln EX_{ij} &= r_i + r_1 \ln GDP_i GDP_j - r_2 \ln D_{ij} + \\ &\quad r_3 \ln DRDS_i DRDS_j + r_4 \ln FDS_i FDS_j \end{aligned} \quad (3)$$

The second term of equation (3) can be arranged as follows:

$$\ln GDP_i GDP_j = -\ln 2 + 2\ln GDPT_{ij} + \ln SIMGDP_{ij} \quad (4)$$

where $GDPT_{ij} = GDP_i + GDP_j$ and

$$SIMGDP_{ij} = 1 - \frac{GDP_i^{\,2}}{(GDP_i + GDP_j)^2} - \frac{GDP_j^{\,2}}{(GDP_i + GDP_j)^2}$$

It is clear that the total volume of trade should be higher, the larger the overall market size (i.e. GDPT), which is equivalent to the average GDP, for given relative size and factor endowments. SIMGDP measures the similarity in the levels of GDP in the trading partners, capturing the relative size of two countries in terms of GDP. This variable may vary within the range of 0 (absolute divergence in size) and 0.5 (equal country size). The larger this measure is, the more similar the two countries in terms of GDP, the higher the share of intra-industry trade.

Similarly, the fourth and fifth terms of equation (3) can be expressed as follows:

$$\ln DRDS_i DRDS_j = -\ln 2 + 2\ln DRDST_{ij} + \ln SIMDRDS_{ij} \quad (5)$$

$$\ln FDS_i FDS_j = -\ln 2 + 2\ln FDST_{ij} + \ln SIMFDS_{ij} \quad (6)$$

where $FDS_{i(j)t}$ is country i(j)'s total inward FDI stock and $DRDS_{i(j)t}$ is country i(j)'s domestic R&D capital stock.

$$FDST_{ij} = FDS_i + FDS_j$$

$$SIMFDS_{ij} = 1 - \frac{FDS_i^{\,2}}{(FDS_i + FDS_j)^2} - \frac{FDS_j^{\,2}}{(FDS_i + FDS_j)^2}$$

$$DRDST_{ij} = DRDS_i + DRDS_j \ ,$$

$$SIMDRDS_{ij} = 1 - \frac{DRDS_i^{\,2}}{(DRDS_i + DRDS_j)^2} - \frac{DRDS_j^{\,2}}{(DRDS_i + DRDS_j)^2}$$

The overall rather than bilateral FDI stock is used for the following reasons. Firstly, most MNEs are located in several countries rather than in the trading partner country only. Secondly, FDI not only contributes to intra-firm trade but also accounts for product variety enlargement and quality improvement since FDI is often regarded as one main conduit of technology spillovers. Finally, the complete data set for bilateral FDI stocks are unavailable for the entire time period under investigation. SIMFDS measures the similarity in inward FDI stocks in the trading partner countries. Similar to the argument for GDPT and SIMGDP, when the total inward FDI is given, the intra-firm trade and the number of varieties consumed between two countries would be higher if the sizes of two countries' inward FDI stocks are more similar. DRDST is total R&D stock of the bilateral trading partners, stressing the role of domestic knowledge accumulation in determining bilateral trade. SIMDRDS captures the technological difference or similarity between the bilateral trading countries. Again, theoretically, it varies from 0 to 0.5.

Because the transaction and transportation costs can be measured by the differences in relative factor endowments (RLFAC) and geographical distances (GD) between countries i and j, these variables may be used to replace the distance index D.

$$\ln D_{ij} = r_5 RLFAC_{ij} + r_6 GD_{ij} \quad (7)$$

where $RLFAC_{ijt} = |\ln(K_{jt}/L_{jt}) - \ln(K_{it}/L_{it})|$ with K and L denoting capital stock and labour force, respectively. RLFAC measures the similarity in capital-labour ratios, or the distance between the export and import countries in terms of relative factor endowments. If it equals 0, this implies that the two countries have the same proportion of factor endowments.

Substituting equations (4)-(7), we have

$$\ln EX_{ij} = \beta_1 RLFAC_{ij} + \beta_2 \ln GDPT_{ij} + \beta_3 \ln SIMGDP_{ij} + \beta_4 \ln DRDST_{ij} + \beta_5 \ln SIMDRDS_{ij} + \beta_6 \ln FDST_{ij} + \beta_7 \ln SIMFDS_{ij} + \beta_8 GD_{ij} + \zeta_i \quad (8)$$

where $\beta_1 = -\gamma_5$, $\beta_2 = 2\gamma_1$, $\beta_3 = \gamma_1$, $\beta_4 = 2\gamma_3$, $\beta_5 = \gamma_3$, $\beta_6 = 2\gamma_4$, $\beta_7 = \gamma_4$, $\beta_8 = -\gamma_6$, $\beta_9 = -\gamma_7$, and $\zeta_i = \gamma_i - (\gamma_1 + \gamma_3 + \gamma_4)\ln 2$.

Matyas (1997) suggests that the correct gravity specification should be a three-way model. One dimension is the time effects, capturing the common business cycle or globalisation process over the whole sample of countries. The other two dimensions are the fixed effects, reflecting the time invariant export- and import- country effects. In this study, because the geographical distance variable is used which is time invariant, one dimension of fixed effects is dropped in order to avoid any multicollinearity problem. As a result, equation (8) under a panel data framework becomes:

$$LEX_{ijt} = \beta_1 RLFAC_{ijt} + \beta_2 LGDPT_{ijt} + \beta_3 LSIMGDP_{ijt} + \beta_4 LDRDT_{ijt} + \beta_5 LSIMDRDS_{ijt} + \beta_6 LFDST_{ijt} + \beta_7 LSIMFDS_{ijt} + \beta_8 GD_{ij} + \zeta_i + \zeta_t + \varepsilon_{ijt} \quad (9)$$

where the prefix L indicates logged values. βs represent elasticities. ζ_i and ζ_t are the country-specific fixed and time effects respectively. GD_{ij} is the geography distance between countries i and j. It captures the impact of other time invariant variables such as transaction and transportation costs.

III.2 Data and Methodology Issues

The data set employed in the paper covers 19 OECD countries with Belgium and Luxembourg being treated as a single country over the period of 1980-1998. All variables are in constant dollar prices with 1990 as the base year. The variable measurement and data sources are listed in appendixes. It should be noted that the commonly used set-up of gravity equation is unbalanced, as no country exports to itself. Because of this, the data come up with 5184 observations for the estimation.

Fixed effects vs. Random effects model

There are only very limited applications of a panel framework in the estimation of the gravity equation and one of the very few exceptions is Rose (2004). Egger (2000) suggests that the proper econometric specification of the gravity model in most applications would be one of fixed country and time effects. These fixed effects are due to the omitted variables specific to cross-sectional units (Hsiao, 1986). They can be trade policy measures including tariff and non-tariff barriers and export driving or impeding "environmental" variables. They are not random but deterministically associated with certain historical, political, geographical and other factors (Egger 2000). However, Baldwin (1994) employs a random effects model and Matyas (1997, 1998) does not give preference to the fixed over random effects model or vice versa. Following the discussion of Baltagi (2001) and Greene (2000), this study employs the Hausman test to decide statistically whether a random or fixed effects model would be more appropriate for our data set.

Tests for stationarity

Several methods for testing for panel unit roots have been proposed in the recent literature, including Quah (1992), Maddala and Wu (MW) (1999), Hadri (2000), Levin et al. (LLC) (2002), and Im et al. (IPS) (2003) (for a survey, see Maddala and Kim 1998, the 1999 supplement of *Oxford Bulletin of Economics and Statistics* and Baltagi 2001). Panel unit root tests address the problem of low power associated with Augmented Dickey Fuller (ADF) tests for unit roots. In this paper, we report three most popular forms of panel unit root test statistics, LLC, IPS and MW. Comparing these tests, all three specify the null hypothesis of the unit root, but LLC tests a homogenous alternative in which every series in the panel is stationary with the same speed of reversion, while IPS and MW test a heterogeneous alternative in which at least one series in the panel is stationary. Maddala and Wu (1999) show that the MW test is more powerful than the IPS test which is in turn more powerful than the LLC test. Due to the MW test's superior size and power properties and its permission for heterogeneity of cross sectional units within the panel, our discussion later will focuses on MW test results. The choice of the deterministic terms in the panel data unit root test regressions, i.e. the inclusion of an intercept or an intercept and a linear trend, is based on whether the time dimension of the series under study exhibits clear trends. If the answer is yes, then a linear trend is included in order to increase power against the possible trend-stationarity of the variable. The order of the regression is determined by the Akaike Information Criterion (AIC) because it is more suitable than other criteria for a short time span.

Tests for exogeneity

New trade, FDI and new growth theories suggest that GDP, FDI and domestic R&D stock are likely to be endogenous variables. If this is the case, a straightaway estimation of equation (9) will be biased. Therefore, test for endogeneity should be applied. If the null hypothesis of exogeneity is rejected, LGDPT, LFDST and LDRDT should be treated as endogenous variables and an instrumental variable method – the generalised method of moments (GMM) proposed by Arellano and Bond (1991) will be employed. The advantage of GMM over other instrumental variable (IV) methods is that the GMM estimator is more efficient than IV estimator if heteroskedasticity is present, whereas the GMM estimator is not worse asymptotically than the IV estimator if heteroskedasticity is not present. However, despite the advantages of using GMM, consistency of the GMM estimator depends on the validity of the instruments. To address this issue we consider the Sargan test which tests the overall validity of the instruments by analyzing the sample analog of the moment conditions used in the estimation process.

IV. Empirical results

Table 2 presents the descriptive statistics for the variables used in the estimations. There is substantial variation in variables. Because all variables except RLFAC exhibit clear trends, all tests except those for RLFAC have included an intercept and a linear trend, while those for RLFAC have included an intercept only. The results of all LLC, IPS and MW panel unit root tests suggest that, for LEX, LGDPT, LSIMGDP, LFDST, LSIMFDS and LER, the null hypothesis of a unit root can be rejected at the conventional significance levels. In other words, these variables are stationary. However, for the remaining three variables, i.e. RLFAC, LDRDT and LSIMDRDS, the LLC, IPS and MW tests point to conflicting conclusions. LLC tests suggest LSIMDRDS is I(2). IPS tests suggest RLFAC and LDRDT are I(1) and LSIMDRDS is stationary. MW tests suggest that all three variables are stationary. As discussed in the preceding section, while the LLC test leads to substantial improvements over the ADF test in terms of power, it is based on the restrictive assumption of common unit root process, while IPS and MW tests assume individual unit root process. Comparing the latter two tests, MW is more powerful. Thus, our conclusion should be in favour of the MW test results that all variables under investigation are I(0). This indicates that there may exist a long run relationship between the variables. We also performed panel data unit root tests for residuals and found that all three tests provides a consistent result that residuals are stationary.[4]

[4] The results are available from authors upon request.

<Table 2 Here>

The procedure of our regression analyses is to start from a simple equation without considering endogeneity, and moving subsequently to equations with country and period effects and endogeneity being taken into account. The empirical results are summarized in tables 3-5.

IV.1 Preliminary Results

We first perform regressions in levels without considering endogeneity. As such a model misses the dynamics of the linkages between the variables, the purpose is primarily to look for simple and static relationships. Table 3 reports the results derived from the ordinary least squares (OLS), FE1 (one-way fixed effects include only country effects), RE1 (one-way random effects include only country effects), FE2 (two-way fixed effects include country and time effects) and RE2 (two-way random effects include country and time effects) models in order.

<Table 3 Here>

From the respective Lagrange multiplier and likelihood ratio test statistics of 10310.62 and 727.46, the assumption of no groupwise heteroscedaticity is rejected. This suggests that there is heterogeneity among each country's export activities. A simple OLS regression of a straightforward pooling of all observations without considering heterogeneity will lead to an unacceptable degree of aggregation bias or even meaningless results. In addition, according to the respective Lagrange multiplier and likelihood ratio test statistics of 25869.26 and 1520.38, the time effects should be considered in the estimation. Finally the significant Hausman statistic of 21.73 indicates that the two-way random effects model performs better than the two-way fixed effects model. The estimates for the country and year dummies are not reported. We simply note that these dummies help pick up country-specific and cyclical factors.

The results in Table 3 are consistent with expectations. In any regression, the coefficients of all the variables are highly significant and have the expected signs. The results suggest that the economic similarity, market size, R&D and FDI stocks and similarity are the powerful determinants of bilateral trade. The geographical distance remains the most powerful in explaining bilateral trade, which is consistent with the results from most gravity model based empirical studies. The distance in relative endowment has a negative sign and is highly significant in all regressions. This is consistent with new trade theory as intra-industry trade plays a more important role than inter-industry trade in OECD countries.

IV.2 Results with Consideration of Endogeneity

A large amount of literature on economic growth shows a two-way relationship between GDP, inward FDI and domestic R&D stock. The Wu-Hausman tests for endogeneity with null hypothesis of exogeneity are performed. The significant test statistics indicate that without proper treatment of endogeneity, the estimation would be biased. Therefore, the GMM technique is applied. The Sargan tests of over-identifying restrictions indicate that there is a serious problem with the validity of the instrumental variables in columns (4.1) and (4.4). Nevertheless the estimated coefficients can be seen to be very similar to those in other columns. There are no significant differences between the parameters estimated using different sets of instrumental variables, denoting the robustness of our estimates. In addition, these new results are also quite consistent with the preliminary results.

<Table 4 Here>

Because the likelihood ratio tests strongly suggest the inclusion of the country and year dummies, in what follows we only comment upon the two-way fixed effects results. All coefficient estimates have the signs which are consistent with theory and statistically significant. The values of the coefficients on RLFAC are between -0.26 and -0.32, indicating that, when the difference in factor endowment between the trading partners reduces by 1%, bilateral trade will increase by about 0.26% - 0.32%. As the bulk of bilateral trade in OECD countries is intra-industry trade, this negative relationship is well expected by new trade theory.

The coefficients of around 0.08 and around 0.10 on LGDPT and LSIMGDP respectively indicate that both the level and the similarity of GDP are the positive determinants of trade flows in OECD countries. These results are consistent with several gravity model based empirical studies including Egger (2000).

We are particularly interested in the impact of FDI and R&D on trade flows. The values of the coefficients on the total FDI stock and the similarity variable in the two-way fixed effects specifications are around 0.17 and around 0.28 respectively, showing a positive relationship between FDI and trade flows. The results suggest that FDI and trade are generally complements in these countries during the sample period. It must be noted that the magnitudes of the coefficients on the FDI variables are not substantial: a 1% increase in inward FDI stock leads to a merely 0.17% increase in bilateral trade.

In terms of the magnitude, domestic R&D seems to play a more important role than GDP and FDI in promoting bilateral trade. A 1% increase in total domestic R&D stock increase bilateral trade by up to 1%, and a 1% increase in the R&D similarity raises trade by abound 0.4%. These results lend strong support to new growth theory. Indeed, R&D is the second important variable in explaining recent trade flows in the OECD countries just after the geographical distance which captures transaction and transportation costs.

V. Conclusions

In this paper, we attempt to forward our understanding and knowledge on the main causes of recent trade flows in OECD countries. Various hypotheses are developed from new trade, FDI and economic growth theories. The simple gravity equation, which contains the GDP and the transaction and transportation cost variables only, is extended to incorporate such important variables as R&D and FDI. The panel data approach is applied to the estimation of the augmented gravity equation. The data set covers 19 OECD countries over the period 1980-1998.

The results indicate that geographical distance is the most important determinant of recent trade flows in terms of the magnitude. Total domestic R&D stock is also a very important cause of trade flows. The importance of the remaining explanatory variables is in the following order: R&D similarity, inward FDI similarity, level of GDP, factor endowment similarity, GDP similarity, and total inward FDI stock. As all the coefficients are statistically significant, the findings lend support to new trade, FDI and economic growth theories.

The introduction of transportation costs into the gravity model reduces the sample size because observations on this variable are only available from 1980-1994. The findings from this sub-sample suggest that trade flows are negatively related to transportation costs. This change has little impact on the general findings obtained from the full sample estimation. Consequently, the results are not reported in this paper, but are available on request from the authors. As the regression results only experience very small changes when the number of explanatory variables and the sample size change, the econometric model specified can be regarded as stable and robust.

The main features of this study include (1) the extension of the original gravity model by incorporating R&D and FDI according to economic theory; (2) the panel unit root tests to confirm the stable or long run relationship between trade flows and its explanatory variables; and (3) the careful treatment of the endogeneity problem. With these the current study should contribute to the theoretical and especially empirical literature on the determinants of trade flows.

The results from this study have important implications for policy makers. New growth theory suggests that domestic R&D, international trade, inward FDI and economic growth can be closely inter-related. This study confirms not only that GDP, R&D and FDI are the important determinants of international trade, but also that the two-way relationship exists between these variables. Thus, the encouragement of domestic R&D, trade and inward FDI enhances economic growth, which in turn promotes more R&D, trade and inward FDI. Put another way, there can be a virtuous circle among these variables.

Appendix 1. Country list:

Australia, Austria, Belgium-Luxembourg, Canada, Denmark, Finland, France, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, UK, United States.

Appendix 2. Variable Measurement and Data Sources

Variable	Measurement and Source
EX	Exports of goods and services (constant 1990 US$), Source: Direction of Trade Statistics Yearbook, IMF. Deflator: GDP deflator, Source: World Development Indicator CD-ROM, 2000.
K	Gross domestic fixed investment (constant 1990 US$)
L	Total labour force, Source: World Development Indicator CD-ROM, 2000.
GDP	GDP at market prices (constant 1990 US$)
FDS	FDI stock, from The World Investment Report, The International Direct Investment Statistics Yearbook and The World Investment Directory.
R&D	Domestic R&D stock (constant 1990 US$)
GD	Geographical distance (in radians of the unit circle between country centroids, based on Joseph Hirschberg's calculation using the SAS-Graph dataset), Source: Boisso and Ferrantino (1997).

Appendix 3. Estimations of Capital Stocks and R&D Stocks

Capital stocks and R&D stocks are estimated mainly from available gross domestic fixed investment and R&D expenditure flows data from World Development Indicator CD-ROM by the standard perpetual inventory calculation method. Data for gross domestic fixed investment for some countries in some years were missing from World Development Indicator CD-ROM which are then calculated from gross domestic fixed investment (constant 1987 price) from Nehru and Dhareshwar (1993). As in Miller and Upadhyay (2000), the following procedure was taken to estimate the capital stock series:

Step 1: Initialise the capital stock by setting

$$K_0 = I_0/(\lambda g_d + (1-\lambda)g_w+\delta) \tag{A.1}$$

where the initial year is 1960; g_d is the average growth rate of the GDP series for the country in question; g_w is the world growth rate estimated at 4 per year; $\lambda = 0.25$, is a measure of mean reversion in the growth rates, following Easterly et al. (1993) and $\delta = 0.5$, is the assumed rate of depreciation.

Step2: Estimate the capital stock using the standard perpetual inventory method

$$K_t = I_t + (1-\delta)K_{t-1} \tag{A.2}$$

R&D stock data in 1980 are taken from Coe and Helpman. Note, because their data is for the beginning of the year, while the data used here are all for the end of the year., their data in 1981 are used for 1980. Then the perpetual inventory method is applied with the depreciation rate assumed to be 5. The data are in 1990 prices, based on PPP exchange rates.

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Table 1: Intra-industry trade index[a] for OECD 22, by commodity and by year

Unit: %

COMMODITY	1993	1994	1995
0 FOOD LIVE ANIMALS	97.8	97.9	98.3
1 BEVRGS TOBACCO	95.2	94.7	96.0
2 CRUDE MATRLS	94.4	94.8	96.0
3 MINERAL FUELS	93.9	95.0	95.1
4 ANIMAL VEG OIL	97.1	96.9	96.2
5 CHEM PRODS	98.0	98.3	96.0
6 BASIC MANUFACT	96.1	97.4	98.0
7 MACHS TRNSPT EQPT	99.1	98.9	98.7
8 MISC MANUFACT	96.4	97.1	97.5
9 GOODS NOT BY KIND	92.3	93.2	97.7

Source: NAPES Database[5]

Table 2 Descriptive Statistics and Panel Data Unit Root Test Results

Variable	Max.	Min.	Mean	s.d.	LLC	IPS	MW
LEX	12.014	0.720	6.821	1.763	-10.914***	-16.977***	1281.36***
RLFAC	1.339	0.000	0.461	0.314	-9.748***	1.450	689.21**
D(RLFAC)						-32.100***	
LGDPT	28.869	25.214	27.219	0.863	-6.945***	-6.167***	949.41***
LSIMGDP	-0.687	-2.854	-1.257	0.559	-5.735***	-4.458***	859.424***
LFDST	13.817	7.778	11.077	1.153	-12.705***	-17.162***	1222.32***
LSIMFDS	-0.693	-4.647	-1.389	0.741	-3.688***	-7.433***	943.421***
LDRDT	28.739	21.043	25.528	1.379	-5.042***	6.109	1017.64***
D(LDRDT)						-15.745***	
LSIMDRDS	-0.689	-6.482	-1.600	1.026	220.628	-19.050***	1248.16***
D(LSIMDRDS)					181.391		
D^2(LSIMDRDS)					-619.275***		
GD	3.067	0.026	0.932	0.906			
LER_W	6.269	0.002	1.008	1.101	-5.942***	-12.726***	1066.98***
LER	7.966	0.000	1.379	1.691	-7.064***	-13.255***	1091.86***

Notes:

1. Variable definitions are provided in the text. D and D^2 denote the first-order and second-order differences, respectively.
2. There are 5814 observations for all variables over the period of 1980-1998.
3. Max., Min. and s.d. denote maximum, minimum and standard deviation, respectively.
4. ** and *** denote significance at the 5% and 1% level, respectively.

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[5] Note: [a]Intra-Industry Trade Index (by commodity) is defined as:

$$IIT_{ij}^{k} = \frac{\left(\sum (X_{ij}^{k} + M_{ij}^{k}) - \sum \left| X_{ij}^{k} - M_{ij}^{k} \right|\right)}{\left(X_{ij}^{k} + M_{ij}^{k}\right)}$$

where X_{ij}^{k} are exports from country j to country k in industry i and M_{ij}^{k} are imports into country j from country k in industry i.

Table 3: Main Sources of Trade Flows in OECD Countries (OLS, FE and RE Estimations)

	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)
	OLS	FE1	RE1	FE2	RE2
RLFAC	-0.316 (0.038)***	-0.267 (0.039)***	-0.268 (0.039)***	-0.253 (0.034)***	-0.254 (0.034)***
LGDPT	0.110 (0.017)***	0.096 (0.022)***	0.097 (0.021)***	0.117 (0.019)***	0.117 (0.019)***
LSIMGDP	0.029 (0.024)	0.057 (0.024)***	0.057 (0.024)***	0.077 (0.021)***	0.076 (0.021)***
LFDST	0.207 (0.016)***	0.260 (0.018)***	0.258 (0.018)***	0.591 (0.020)***	0.583 (0.019)***
LSIMFDS	0.290 (0.020)***	0.279 (0.020)***	0.279 (0.020)***	0.490 (0.019)***	0.486 (0.019)***
LDRDT	0.882 (0.016)***	0.779 (0.019)***	0.783 (0.019)***	0.840 (0.017)***	0.842 (0.017)***
LSIMDRDS	0.301 (0.017)***	0.295 (0.018)***	0.295 (0.018)***	0.406 (0.017)***	0.404 (0.017)***
GD	-1.131 (0.013)***	-1.113 (0.015)***	-1.113 (0.015)***	-1.135 (0.014)***	-1.135 (0.014)***
Country Effects	Not Included	Included	Included	Included	Included
Year Effects	Not Included	Not Included	Not Included	Included	Included
Adj-R^2	0.744	.77385		.82535	0.7470
Various Diagnostic tests		LR[17] = 727.46***	LM[1]= 10310.62***	LR[18]= 1520.38***	LM[2]= 25869.26***
			HS[8]= 8.35***	LR[36]= 2247.84***	HS[8]= 21.73***

Notes:

1. Standard errors are in parentheses, and values of degrees of freedom are in square brackets.
2. ***, **, and * indicate that the coefficient is significantly different from zero at the 1%, 5% and 10% levels respectively.
3. The likelihood ratio (LR) statistic is applied to test the country and year fixed effects.
4. The Lagrange multiplier (LM) statistic is applied to test the country and year random effects.
5. The Hausman statistic is applied to test between fixed effects and random effects.

Table 4: Main Sources of Trade Flows in OECD Countries

(GMM Estimation)

	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)
RLFAC	-0.316 (0.038)***	-0.270 (0.038)***	-0.260 (0.035)***	-0.315 (0.038)***	-0.271 (0.023)***	-0.264 (0.026)***
LGDPT	0.103 (0.017)***	0.085 (0.021)***	0.099 (0.019)***	0.100 (0.017)***	0.078 (0.007)***	0.089 (0.009)***
LSIMGDP	0.036 (0.023)	0.059 (0.024)***	0.076 (0.021)***	0.042 (0.024)***	0.061 (0.010)***	0.077 (0.012)***
LFDST	0.209 (0.016)***	0.270 (0.019)***	0.583 (0.021)***	0.208 (0.017)***	0.275 (0.052)***	0.580 (0.013)***
LSIMFDS	0.315 (0.021)***	0.305 (0.021)***	0.501 (0.020)***	0.335 (0.022)***	0.325 (0.044)***	0.511 (0.012)***
LDRDST	0.922 (0.016)***	0.828 (0.020)***	0.871 (0.018)***	0.944 (0.017)***	0.861 (0.073)***	0.885 (0.020)***
LSIMDRDS	0.327 (0.019)***	0.330 (0.020)***	0.421 (0.018)***	0.339 (0.020)***	0.352 (0.064)***	0.426 (0.014)***
GD1	-1.128 (0.013)***	-1.106 (0.015)***	-1.124 (0.014)***	-1.127 (0.013)***	-1.103 (0.006)***	-1.117 (0.009)***
Country Effects	Not Included	Included	Included	Not Included	Included	Included
Year Effects	Not Included	Not Included	Included	Not Included	Not Included	Included
Sargan Test	663.804***	0	0	647.78***	0	0

Notes:

1. Standard errors are in parentheses, and values of degrees of freedom are in square brackets.
2. *** indicates that the coefficient is significantly different from zero at the 1% level.
3. The Sargan test is applied to test over-identifying restrictions.
4. The instruments used in (4.1) – (4.3) are explanatory variables lagged one period and dummies and the instruments used in (4.4) – (4.6) are explanatory variables lagged two period and dummies.